

STRESSING

I. Preparation for Stressing Inspection

One of the most essential preparations for stressing inspection is the calculation of theoretical elongations due to jacking. Recommended practice is to calculate 80% of theoretical elongation, and to compare field measurements taken between 20% and 100% of jacking force. This should eliminate the effect of dead end seating loss, cable slack, and variation in the modulus of elasticity (E) of the strand at lower stress ranges. This is not a hard and fast rule. If variations are encountered or long cable lengths are to be stressed, one can base comparisons on a calculated 70% or 75% of the theoretical elongation.

It is the responsibility of the Contractor to submit elongation calculations as part of the working drawings. Structure Design and the Structure Representative then check the Contractor's calculations. Appendix D gives an acceptable method of calculating elongations as well as force factors.

Tendon elongations are calculated on the basis of an assumed modulus of elasticity (E) - usually 27,500 ksi for strand, The strand area is commonly assumed to be 0.153 square inches. The actual E and cross-sectional area (A) will be shown on the-materials release tag for the prestressing steel and the elongations should be re-

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calculated to be consistent with those figures, In other words, actual E and A must be used to calculate elongations. However, do not recheck the minimum required area (A) based upon the actual values. Often packs of strand arrive with varying E and A. In this case, it is best to separate the strand so that all strand in a given tendon are the same. However, if the variations are small, tracking the varying strands in each tendon and using an average E and A is acceptable. Appendix D gives examples of elongation calculations.

Prior to stressing, it is also necessary to make preparations for monitoring the jacking force. The Standard Specifications (Section 50-1.08) require the Contractor to have an accurate load cell or pressure gage on each jack and that the jack/gage combination be accompanied by a certified calibration chart. Recertification should be done at least every 12 months. The Contractor's jack and gage are usually monitored by State pressure cells during stressing. Up to date information regarding jack calibration is available by accessing the Structure Construction computer bulletin board.

The Engineer in charge of field inspection of stressing should be familiar with the calibration chart and pressure cell prior to stressing. Appendix B gives instructions in the use and care of the pressure cell and Bridge

Construction Records and Procedures Memo 160-3.0 gives administrative instructions relevant to the pressure cell.

II. Field Inspection

The practice of stressing both simple span and some continuous structures from one end only is allowed only when shown on the contract plans or specifications. When two end stressing is required, the Contractor must stress both ends to P_{jack} either simultaneously or non-simultaneously and show the actual method of stressing on the working drawings.

In order to minimize the possibility of undesirable construction stresses, Standard Plan B8-5 states, " No more than 1/2 of the prestressing force in any girder may be stressed before an equal force is stressed in the adjacent girders. At no time during the stressing operations will more than 1/6 of the total prestress force be applied eccentrically about the centerline of the structure." However, please note that the 1/6 factor is often modified for railroad structures.

If compliance with these requirements is overly difficult because of a particular tendon arrangement, Structure Design should be consulted.

In order to efficiently monitor stressing operations, a record in chart form must be kept for each tendon stressed. Figure 6 is an example of such a chart. Note that some of the information shown can be entered prior to stressing.

DEPARTMENT OF TRANSPORTATION

Date Tendons Placed _____

Br. Name

Br. Number

Contract #

[illegible]

- Notes:
1. Subtracting $\frac{1}{4}$ " from the measured elongation is due to the strand elongation inside the jack. This is calculated by multiplying $\frac{1}{12}$ inch per foot of strand between the anchor and pulling wedges at P_{jack} .
 2. For two end stressing, use a second form for the second end. Summarize the data in the last three lines on one of the two forms.
 3. For non-simultaneous two-end stressing, the anchor load will be in excess of 20% P_i at the second end. However, it is suggested that the measurement be taken at 20% P_i to be consistent.

FIGURE 6 CHART TO MONITOR STRESSING OPERATION

Remember, that this form is a guide. You may desire to custom design your own chart.

Each individual strand should be marked or painted at both ends of the structure to measure elongation and check for slippage. Tendons should be checked during and after stressing for any strand slippage or dead end seating loss, The area of 1/2" prestressing strand typically varies between 0.151 and 0.154 square inches. However, some strand has been received with an area as small as 0.149 square inches. Such small strand has presented problems with proper seating of the wedges, Particular care should be used when stressing any strand with an area below 0.151 square inches. With the Dywidag bar system, the elongation can also be monitored by counting the turns of the anchor nut during stressing.

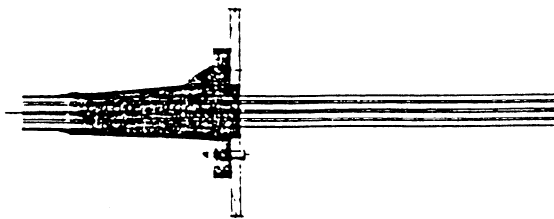
An important requirement of prestressing inspection is obtaining the anchor set shown on the plans. Anchor set is the amount of strand movement at the time of force transfer to the bridge. This is usually 3/8" for continuous structures and per shop plans for simple spans. In most prestress systems, elongation of the tendon occurs within the jack itself. At $0.75 f'_s$, the tendon elongates approximately 1/12" per foot of jack measured from the anchorage to the pulling head. When measuring or computing anchor set, do not include this jack elongation. Refer to

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Appendix D for calculating the effect that anchor set has on tendon stress. For a complete jacking sequence including anchor set, see Figure 7, which is provided by the VSL Corporation.

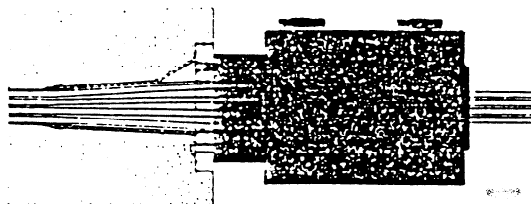
It is the policy of Structure Construction that the pressure cell be used at the start of stressing to verify the Contractor's calibration chart and at least one calibration curve be made per structure or frame, The Structure Representative may require additional monitoring as needed. Figures 8 and 9 are examples of completed forms DS-C 86 and 86A for recording the Contractor's gage readings versus pressure cell readings. These forms shall be submitted upon completion to Structure Construction in accordance with Bridge Construction Records and Procedures Memo 3-1.0. See Appendix C for a complete inspection checklist.

Phase 1



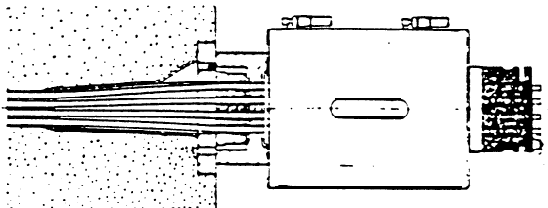
- Bearing plate with sleeve is attached to formwork
- Either rigid tubing without strands or flexible tubing containing strands is placed.

Phase 2



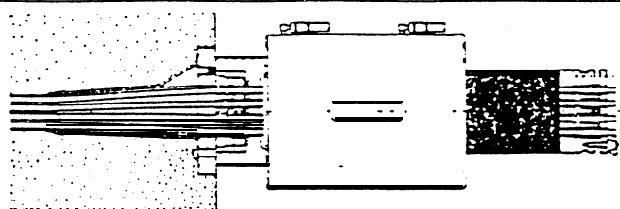
- After curing of concrete, formwork is removed from anchorage zone
- Strands are drawn through duct if rigid tubing is used
- Anchor head and grippers are fitted
- Center-hole jack is placed over strands.

Phase 3



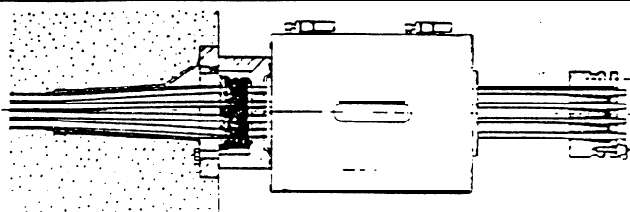
- Pulling head is fitted. If required, a load cell can be placed between pulling head and jack piston.

Phase 4



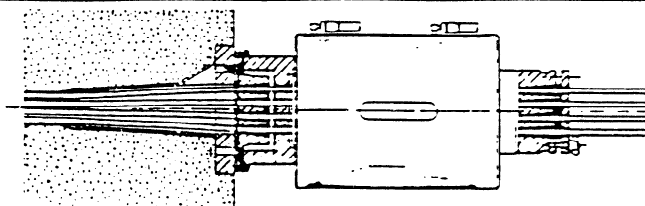
- Tendon is stressed
- Pressure gauge reading and cable elongation are recorded.

Phase 5



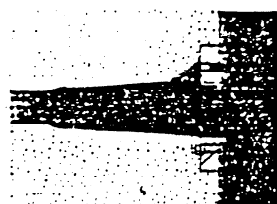
- Jack piston is retracted
- Force is transferred to the structure through anchorage.

Phase 6



- If required, a shim can be placed between anchor head and bearing plate to compensate for anchorage take-up of $\frac{1}{4}$ inch.

Phase 7



- Stressing equipment is removed
- Projecting strands are cut off and anchorage sealed
- Cable is grouted, if required
- Anchorage is capped with concrete.

FIGURE 7 COMPLETE JACKING SEQUENCE

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DEPARTMENT OF TRANSPORTATION

JOB STAMP

PRESTRESS CALIBRATION
MONITORING SHEET

04 - SC1 - 85 - 3.0/5.3
04 - 123454
Wide River Bridge

DS-C86 wp50

DATE: 08 - 31 - 90 STR. REPRESENTATIVE: Joe Bridge
NAME OF SYSTEM: VSL INSPECTOR(S): I. Girder, T. Beam, I. M. Lost

JACK NUMBER: 6 - 10 - 43

GAGE NUMBER: 6 - 10 - 43 B

FOR 1/2" 270 KSI STRAND ABSOLUTE MAX. Pj=31 Kip/Strand X #Strands/Tendon: = 31 Kips X 48 = 1488 K

FOR 0.6" 270 KSI STRAND ABSOLUTE MAX. Pj=44 Kip/Strand X #Strands/Tendon: = 31 Kips X X =

CONTRACT REQUIRED Pj = 1488 K

Theoretical Maximum Gage Pressure: -..... = Pj = 1488 K = 8308 psi
Ram Area 179.1 in.²

Maximum Gage Pressure From Latest Contractors Calibration: 8750 psi

Strain Gage Indicator CHC 13686

Electro Hydraulic Cell Number: 18 Numerical Display Setting: 1094 , Actual Gage Factor: 0-72

Measurable Elongation = 80% Total theoretical ELongation: 28.5"

Gage Reading	Load from Indicator		Load from Calibration Chart				Remarks
1680	297		300				20% P,
2000	352		350				
3000	523		520				
4000	692		690				
5000	855		855				
6000	1025		1025				
7000	1198		1195				
8000	1365		1360				
8720	1488		1480				Meas E long = 29"

FIGURE 8 SAMPLE FORM DS-C86

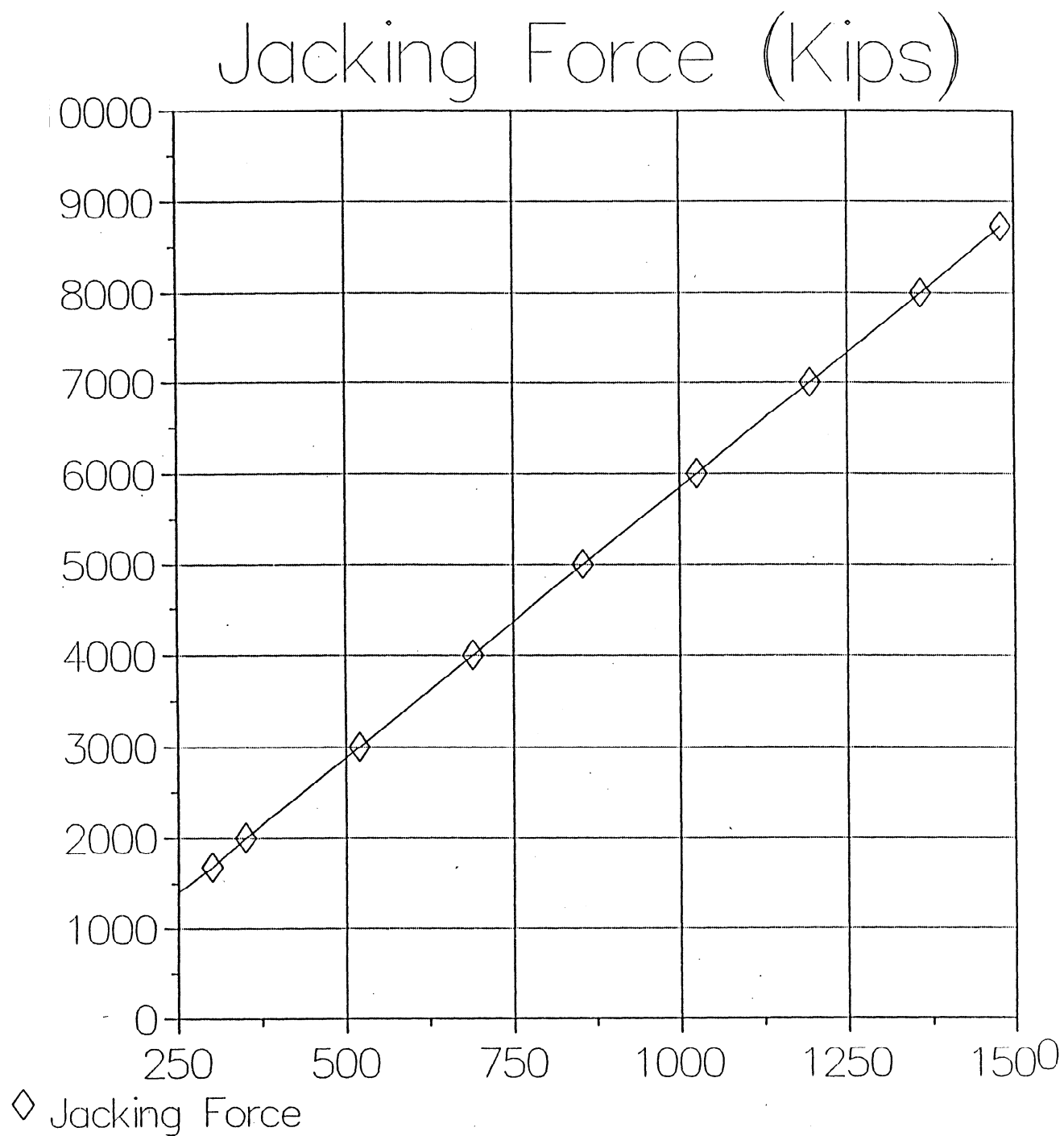


FIGURE 9 DS-C86A

III. Overstressing of Prestressing Steel

Technically, prestressing wire and strand develop high strength and excellent creep characteristics through cold drawing. During this cold drawing process the grain structure is elongated and aligned into a condition resulting in specific physical and mechanical properties.

The three stress-strain curves shown in Figure 10 show a 1/4" cold drawn, stress relieved prestressing wire tendon that had been stressed to 83% of the minimum ultimate strength of the wire.

Note the great difference in the stress-strain relationship between Sample #1 and Samples #2 and #3, keeping in mind that all three samples came from the same tendon. The illustrated variations in physical properties of wire stressed above the proportional limit is one reason that the Standard Specifications do not permit stressing beyond 75% of the specified minimum ultimate strength.

Due to the possibility of wires or strands being of unequal length within a tendon, some of the wire or strands could be stressed to their yield strength, even when the tendon is not overstressed. Therefore, when the jacking force exceeds the 75% limitation, some of the wire or strands in the tendon may be seriously overstressed. This condition is demonstrated by the stress-strain curve for Sample #1 in Figure 10.

When steel such as prestressing wire or strand is stressed beyond its elastic limit or yield strength, some of its physical characteristics change. The most significant changes are in the modulus of elasticity (E) and the creep rate. If these properties are changed by permanently overstressing, the significance of elongation measurements is questionable. Remember, if it appears that the 75% limit is being exceeded - - stop!

The effect of permanent overstressing on physical properties of strand has been demonstrated by laboratory tests in a 100 ft. pretensioning bed as follows:

Initial Jacking Force	Initial percent of Ultimate	Residual Stress @ 72 hrs	Percent Stress Losses @ 72 hrs
34 kips	82.3	26 kips	23.5
28 kips	67.8	27 kips	3.6

This example indicates that strand when kept in an overstressed condition (greater than $0.75 f'_s$) results in a significant reduction of prestressing force due to the change in creep properties of the strand. This is one reason why the maximum anchor stress may not exceed 70% of the ultimate strength of the steel, and the jacking force must not be exceeded.

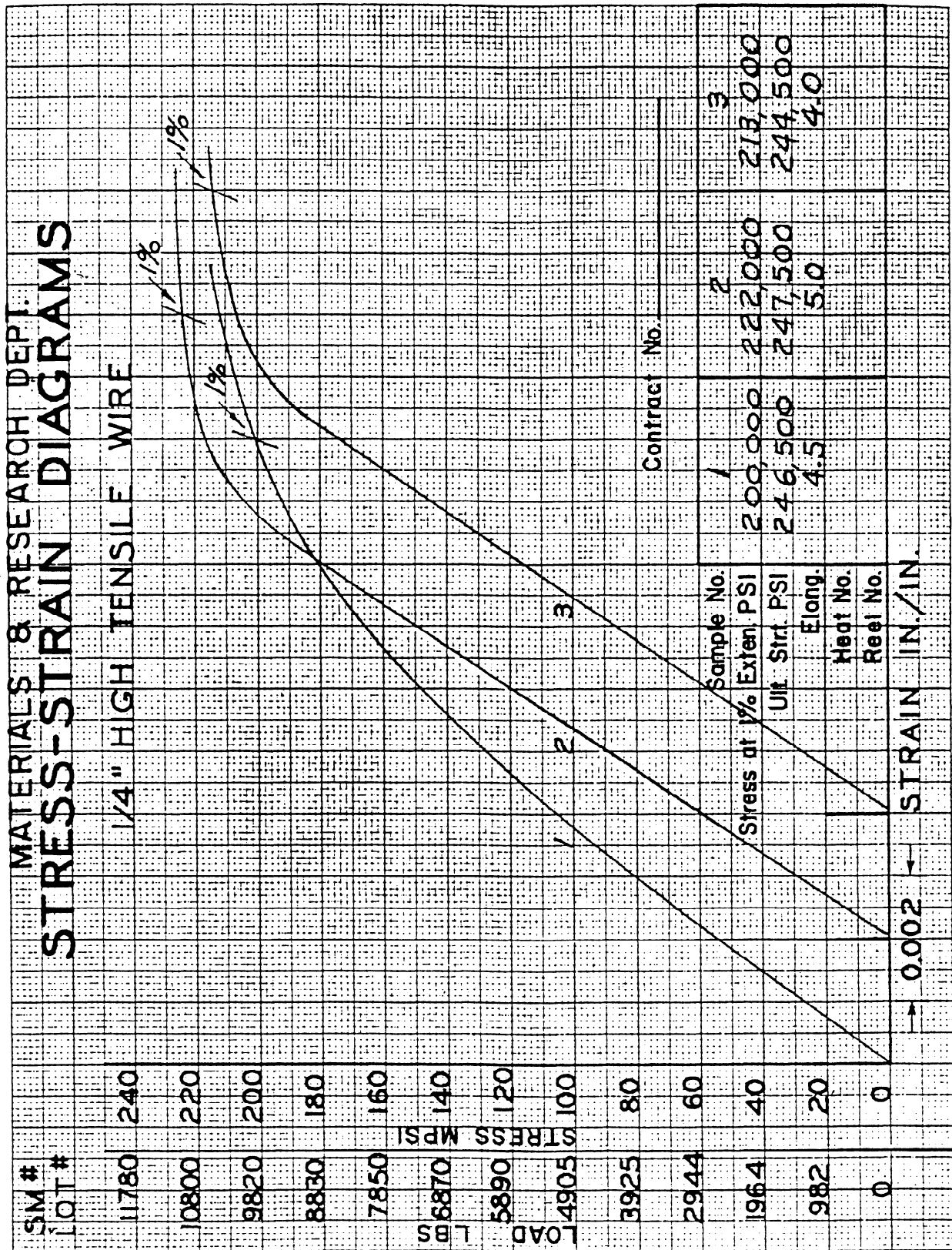


FIGURE 10

IV. Elongation

The measured elongation should substantially agree with the calculated elongation. Since the last edition of the California Prestress Manual, the friction coefficient has been reduced to 0.20 and the wobble correction has been eliminated. However, due to variations in friction factor, elongations tend to run higher than calculated, often by 5% to 10%. This is acceptable as long as the variations are understood and explained; but deviations between elongations of similar tendons of the same bridge should not vary more than 4% +/- . Remember, each case must be carefully examined to assure compliance with the working force required.

The following are possible reasons for elongations not being within the calculated range:

1. Incorrect number of strands placed in the tendons,
2. Excessive wobble of ducts increases friction and decreases elongation.
3. Unusually smooth duct placement decreases friction and increases elongation.
4. Even, layered strand placement reduces friction and increases elongation, particularly when strand are 'pushed' into the duct.
5. A change in jack efficiency is not detected by a pressure cell. This may cause faulty readings.

6. Elongation calculations may be wrong due to the following:
 - a. Incorrect Modulus of elasticity (E) or area of strand (A).
 - b. Incorrect or varying tendon lengths due to skew or sharp radii.
 - c. Differing coefficient of friction between girders on sharply curved structures.
 - d. Different tendon paths in a girder.
7. Incorrect method of measuring elongations.
8. Slippage of strand during stressing, especially if the strand area is small (below 0.151 sq. in.).
9. Gage damaged or indicator not zeroed.

The cause of any inconsistent elongations among the tendons of a structure must be determined as soon as possible. Do not cut off excess strand until the problem is resolved. In the event it is necessary to detension a tendon, stressing contractors must have suitable equipment available for this purpose as required by the TransLab approval procedure.

As a general policy, strand should not be cut off until all tendons in the structure are fully stressed.